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Monitoring of urban growth and its related environmental impacts: Niamey case study (Niger)

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Abstract

The present contribution is about a preliminary study of the evolution of Niamey city (Niger) during last decades.
Recent advances in remote sensing, both in satellite hardware technology and image availability development, provide opportunities image collection and multitemporal analysis on urban form and size that can be useful for policy and planning. Some opportunities for, and limitations on, monitoring urban growth using remote sensing data are shown in the present contribution; moreover examples of environmental impacts of urban growth, as monitored with remote sensing, are provided in order to define future development of dumps and quarries and its environmental impacts on Niamey city.

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Keywords: Satellite Images; GIS; Quarries; Environmental impacts; Niger

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1. Introduction

Niamey is the capital of Niger (Fig.1) and is the first city in the country as dimension, culture and economic importance. Its population increased gradually, from about 3,000 in 1930 to about 30,000 in 1960, rising to 250,000 in 1980 and, according to the official statistics, to 800,000 in 2000. Its patterns of population, livelihoods, and its dominant role within the national economy of Niger make it a good representative case study for West Africa.

The research analyses the enlargement of Niamey City from 1979 to 2014 using satellite images. Moreover, two pilot sites have been investigated to highlight the increasing aggregate quarry activity, probably due to huge population growth.

Fig. 1. Niger is a landlocked developing country located in Western Africa into Sahel Region (ArcGlobe-ESRI).

2. Geological Settings

Geologically the Niamey region straddles between the Liptako, corresponding to the northern extremity of the East ridge of Man, and the south-western edge of the Iullemmeden basin. The Niamey region consists of two main geological units, including:

- The Paleoproterozoic basement (2300-2000 Ma [1]), which includes granitoid plutons alternating with greenstone belts (Fig. 2). Granitoids consist of diorite intrusions, quartz diorite to tonalite, monzonite, granodiorite and granite or syenite locally. These intrusive bodies are either syn-tectonic or post-tectonic [2,3,4,5]. The green rocks consist of sandstones-pelitic rocks more or less metamorphosed (shales, sericite schists, micaceous schists, quartzitic schists) and low to medium metamorphic greenstone (amphibolite, chlorite, metabasalts, metagabbros) [6].
- Overlying formations represented by a lower older unit essentially consisting of Upper Precambrian sediments (Niamey sandstone, grN, Fig. 2) [7, 8] and an upper unit (post Eocene) of the Continental terminal formation (facies Ct3, Fig. 2) and quaternary to recent deposits (facies a and d, Fig. 2).

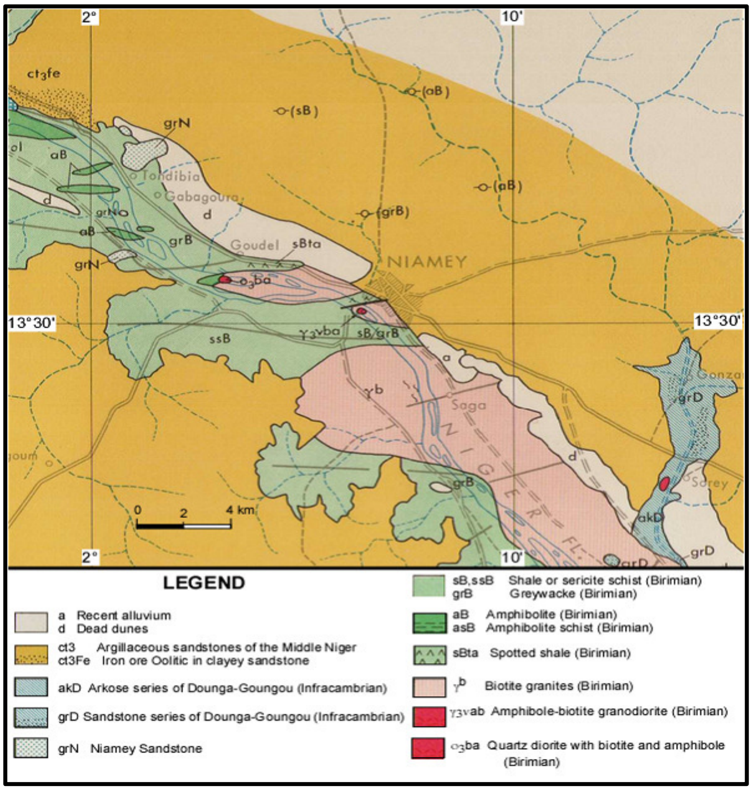

Fig. 2. Geology map of Niamey City (Ousmane et al., 2007)

3. Methodology

During the 2014 season a complete field survey was conducted for the collection of data about quarries, groundwater and surface water [9]. This previous study represents the starting point for the present work, where resources evolution during decades are investigated in detail from satellite.

Recent updating in remote sensing, both in satellite hardware technology (i.e. image availability) and image processing algorithm development, provide opportunities for collection and analysis of multitemporal information on urban shape and size, that can be useful for local policy and planning. In spite of these developments, there are also limitations to remote sensing and its application in practice (i.e. cost of the VHR images). Some opportunities for, and limitations on, monitoring urban growth using remote sensing data are shown; moreover examples of environmental impacts of urban growth, as monitored with remote sensing, are provided.

Thanks to the free Landsat Archive 1972-2016 (USGS glovis.usgs.gov) a multitemporal analysis has been developed (Fig. 3). Six multispectral images from Landsat 2 to Landsat 8 have been selected and analysed according to the most recent satellite data analysis bibliography [10]. The first step was radiometric elaboration in order to obtain reflectance images. Second step was to improve image co-registration in order to detect quarries development during the decades (and the possible evolution of quarries into landfills). Last step was image analysis focused on quarries evolution and city boundaries (Fig. 3). The first analysis was the city boundary multitemporal evolution; thanks to the Landsat multispectral and panchromatic images, a GIS project with boundary evolution from 1979 to 2014 was created (Fig. 4). The second analysis was to detect quarries and dumps evolution for aggregate production within Niamey boundaries (see S5 and S6 in Figs. 4 and 5). The presence of quarries in the S5 and S6 sites is highlighted by false color infrared Landsat synthesis (742 for Landsat 5 and 7 – 753 for Landsat 8–543 for Landsat 2 MSS). In fact thanks to satellites images reflectance, the quarries evolution, from 1979 to 2014, is highlighted. To confirm our hypothesis, during 2014 field campaign we found the transformation of S5 quarry to dump (Fig. 5). The sand quarry S6 evolution (see Fig. 6) is highlighted by the evolution of the fan used for aggregate exploitation activity.

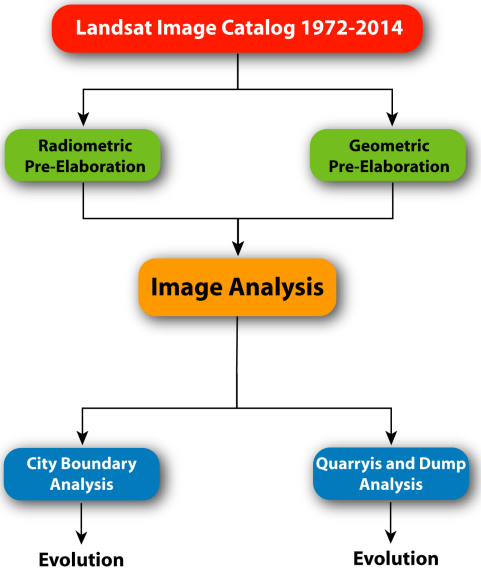

Fig. 3 - Image analysis methodology

3. Results

Since the 30s the population of Niamey City has increased from 3,000 to about 1 million people. Of course, even the city boundaries have enlarged, as shown in the satellite images from 1979 to 2014 (Fig. 4) and the opening of quarries has become the main result.

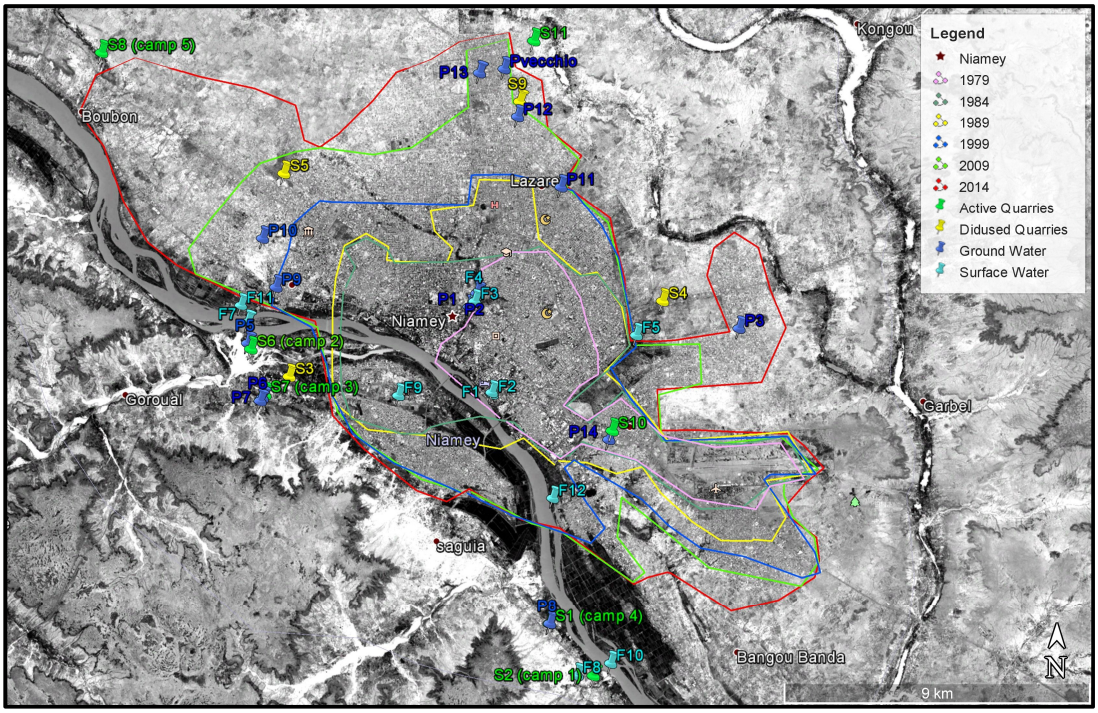

Fig. 4. Niamey city georesources and city boundary multitemporal analysis. Base map Landsat 8 PAN 2014.

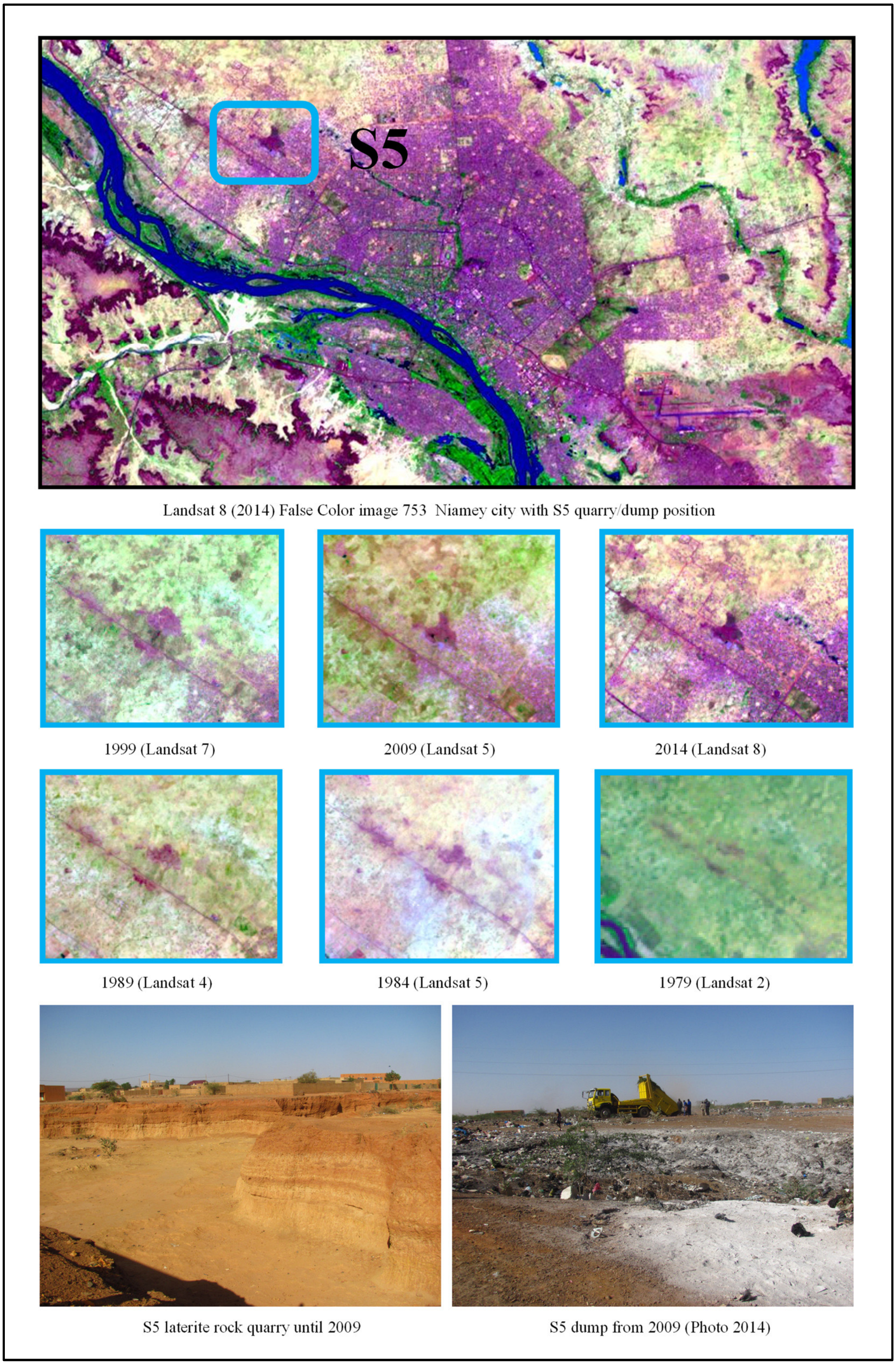

Fig. 5 – S5 site evolution and analysis

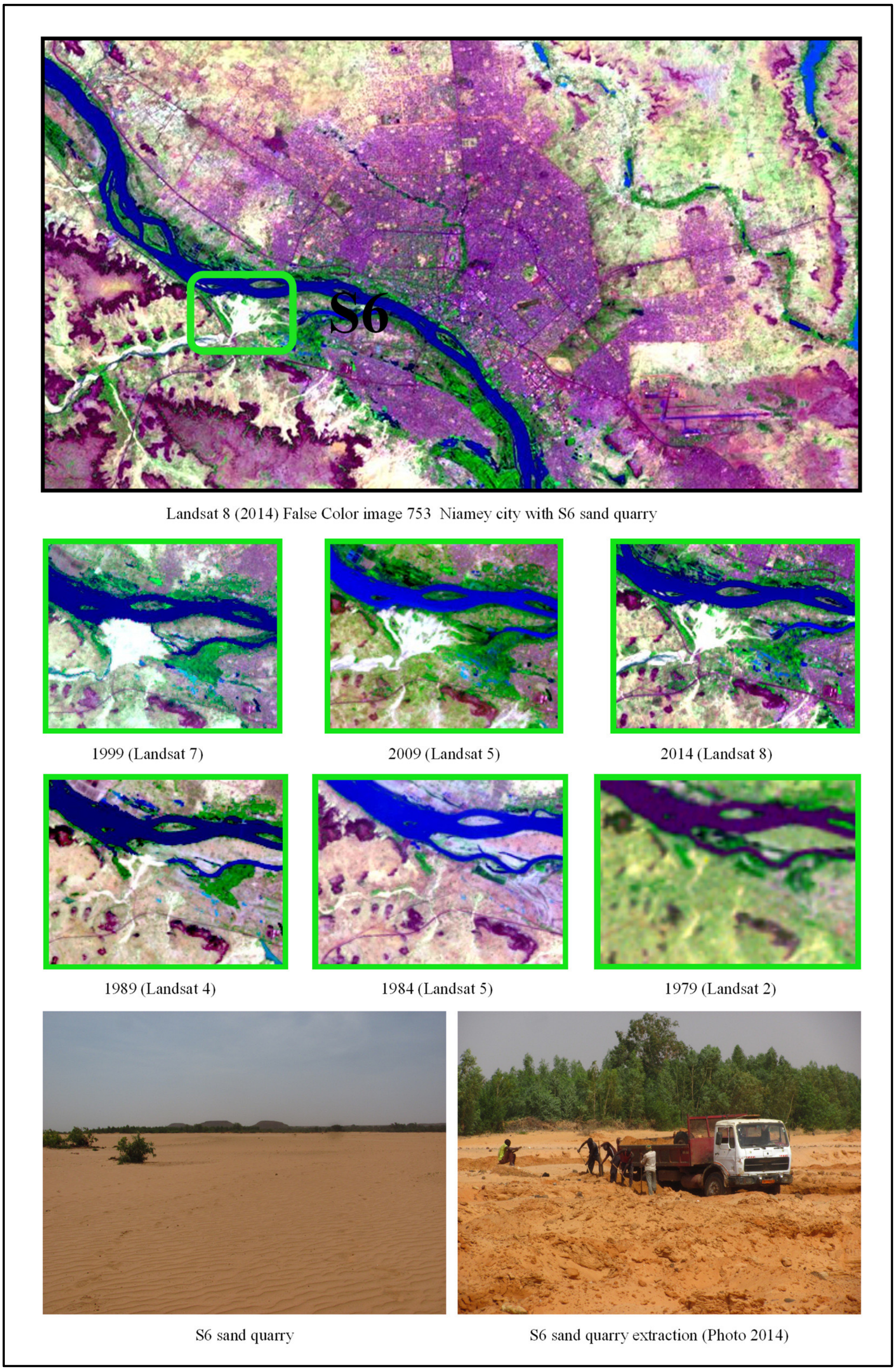

Fig. 6 – S6 site evolution and analysis

The S5 quarry was exploited for laterite rock during city growth from the early 80s; indeed in the 1979 Landsat 2 image the quarry pixels are not clear. It was disused since 2009 and it became a dump before 2014.

The S6 quarry was exploited for sand from the beginning of the 90s and it is still active. In the images (Fig. 6) couple of fans (one big and one little) are growing until 1999 when exploitation started. But recent activity is notable due to the city laterite needs.

4. Conclusions

The important enlargement of the city, highlighted with satellite images from 1979 to 2014, is certainly connected to a larger exploitation and use of aggregates for construction. The evolution of the two quarries, analyzed in the same period thanks to satellite images, has evidenced the potential conversion of quarries into dumps. This situation can create environmental problems and contamination of soil and water (both surface water and groundwater).

The achieved results are important for the identification of the areas which can be easily affected by environmental contamination due to inappropriate waste management.

All the information arising from the present work is useful for local decision makers to enhance Niamey georesources (water and aggregates) management. To plan a correct building and infrastructure activities, a survey about aggregate production and local needs, and about the potential production on recycled aggregates from construction and demolition activities (C&DW), would be necessary. Further information on water quality and quantity is fundamental in a wider perspective of food security and for life quality improvement.

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